Efficiency opportunities in school HVAC systems

Michael K. Fulton, P.E.
York International

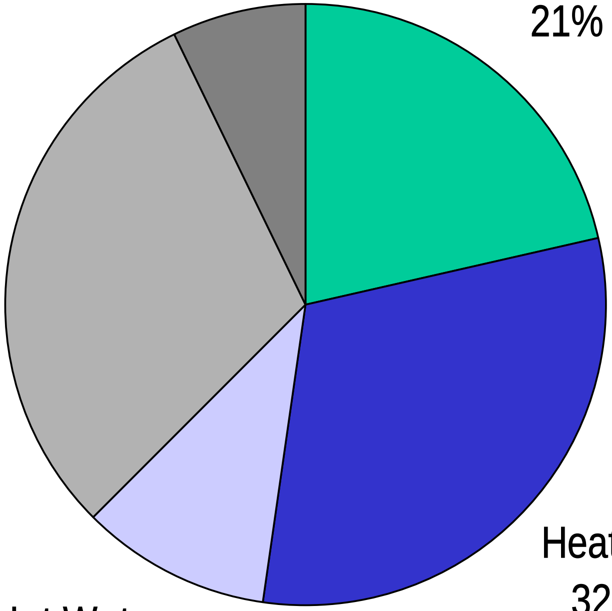
Importance of good HVAC systems

HVAC systems impact:

- Health
- Comfort
- Productivity
- Academic performance
- Energy costs
- Maintenance team

Heating, Ventilating and Air Conditioning (HVAC)

HVAC accounts for 50-60% of energy consumed in schools



Best HVAC design requires integrated design

Considers:

- All interrelated building systems
- Indoor air quality
- Energy consumption and cost
- Environmental benefit
- Acoustics
- Maintenance requirements
- Equipment life
- Replacement costs

Includes:

- Features that provide learning opportunities
- Commissioning to ensure proper operation when occupied

Best HVAC designs require communication

- Among school district, architects, engineers, and multidisciplinary design team
- Begin communication early in schematic design
- Continued communication throughout design, construction, occupancy

Meetings, meetings and more meetings!

Acoustics

- New ANSI standard
- Bad acoustics is common and often hampers learning
- Balance acoustics goals, efficiency goals and ventilation goals

Don't hide it all away…
Design in learning opportunities

Include features that encourage learning:

- Windows to mechanical rooms
- Temperature gauges on pipes and ducts
- Lights to indicate heating/cooling mode
- Exposed pipes and ducts

Remember the goal of a school:

Learning!

Set an energy performance target

Examples:

- Energy Star
- Beat best school in the district
- LEED Certification
- Beat ASHRAE Standard 90.1 by 60%
- 50 cents per square foot per year
- 60 kBtu/sf/year

"If you don't know where you're going, any road will do."

Alice in Wonderland

Example:
Designing for Energy Star – Setting a goal

www.energystar.gov

Money Isn't All You're Saving

Target Finder

- Free, easy online at Energy Star website
- Input size, zip code, and other details
- Automatically outputs target kBtu/sf/year

Using Target Finder to set kbtu/sf/yr goal

1. Facility Information

*Zip Code [ ] Facility Name [ ]

City [ ] State [ ]

2. Facility Characteristics

*Select Space Type(s) for this project.

[Space Types]

3. Target Score

100

*Choose desired target score. Select "**View Results**" to display associated energy use.

Design Energy (optional)
Enter energy source data for your design. Select "**View Results**" to compare estimated energy to your target.

Energy Source	Units	Estimated Total Annual Energy Use[1]	Energy Rate ($/Unit)[2]
Electricity	kBtu		$ /kBtu
[Select Energy Source]			$ /

[1]Annual Energy Use - energy source percentage is determined from DOE-EIA Estimated Electric %, typical of the area designated by zip code. Natural gas is used as 2nd energy source.
[2]Energy Rate - uses the DOE-EIA State Average Fuel Rate to calculate energy cost.

View Results Clear Form

Once you've set a goal, use energy modeling to help get there…

- Choose a modeling tool that can model your school and systems
- Choose an experienced energy modeler
- Begin modeling early in schematic design
- Revise model throughout process
- Use results to inform design decisions

DOE-2

EnergyPlus

TRACE

Require life cycle cost analyses

- Ensure that decisions are based on both initial costs and life-cycle costs (LCC)
- LCC includes:
  - Initial cost
  - Maintenance expenses
  - Annual energy costs
  - Projected labor and energy escalation rates
  - Replacement costs

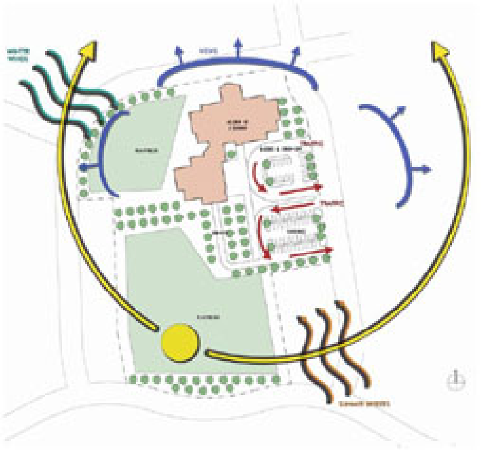
Good HVAC design doesn't begin with the HVAC design…

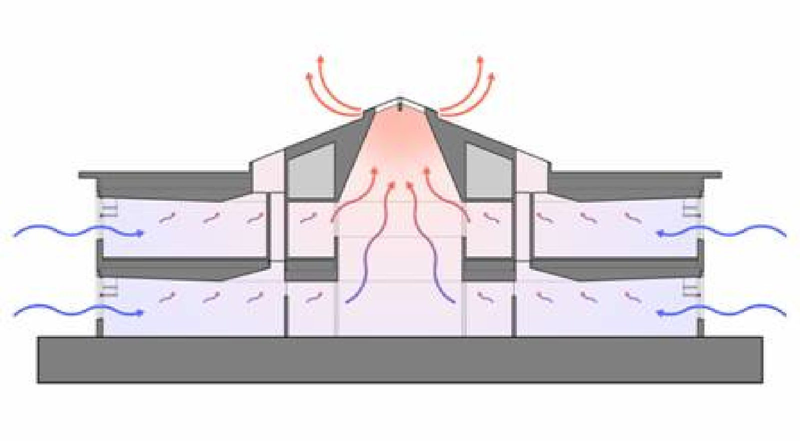
- Design an efficient shell
  - Insulate the entire shell
  - Minimize infiltration
- Control solar gains
- Minimize internal gains
  - Lighting drives HVAC sizing

Integrated design…multidisciplinary team ….communication

Good HVAC design doesn’t begin with the HVAC design…

- Build in opportunities for natural ventilation: orientation, operable windows, stack effect, cross ventilation





Cooling Systems efficiency opportunities

- Consider direct or indirect evaporative cooling
- Ensure design allows for nighttime ventilation for free cooling.
- Consider thermal ice storage to reduce peak demand.
- Consider Underfloor air distribution for 30% actual energy savings.
- Avoid oversizing.
- Evaluate various options using computer simulation.

Developments in Evaporative Cooling

- Efficiency as high as 90%
  - The most efficient cooling available.
  - Might not work at all times due to periods of High Humidity
- Maintenance
  - Periodic replacement of media
  - Scale on piping, pumps, distribution headers
- Water usage
- Costs

Heat Recovery systems

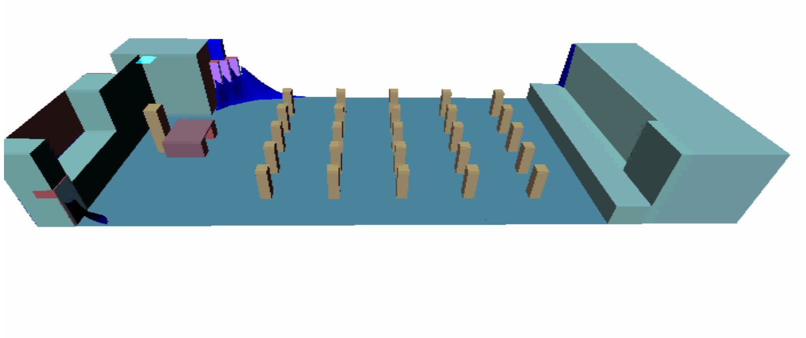
- Air to Air most efficient – up to 80%
- Heat recover Coils – not as efficient, best application is remote airstreams 25 – 45% efficient
- Costs have come down, more economical, often a standard option.

Thermal ice storage systems

- Make ice at night, off-peak
- Melting ice provides cooling on-peak
- Reduces peak electric demand
- Saves on energy costs, slightly higher energy consumption
- Commissioning, monitoring and maintenance essential

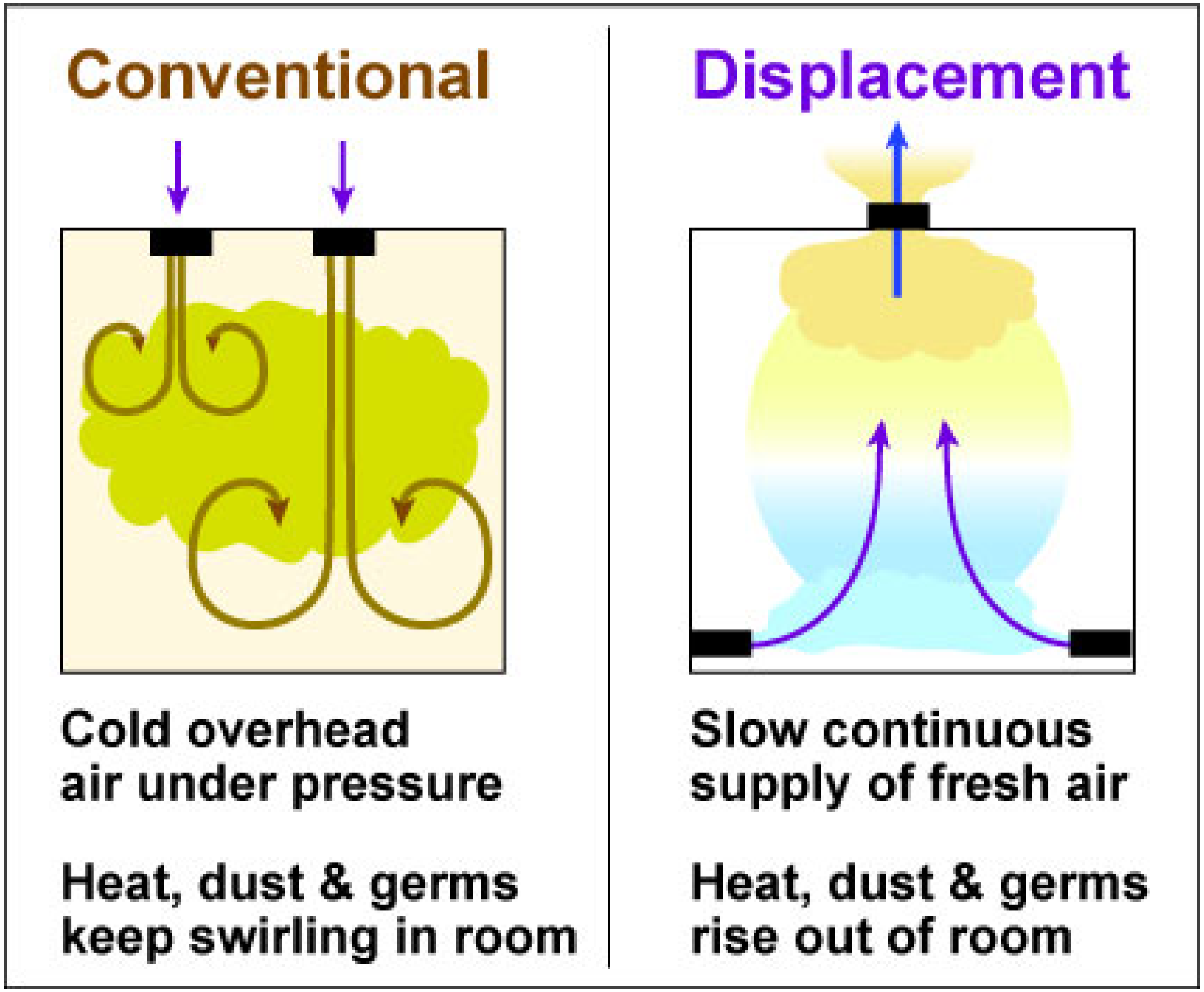
Displacement Ventilation

- Fresh cool air is slowly supplied near the floor.
- Air rises as it warms.
- Air is exhausted near the ceiling.



Courtesy H. L. Turner Group

Conventional vs. Displacement Ventilation



Underfloor Air Delivery Systems

- One pass airflow – IAQ, reduced sick days & Asthma
- 30% less fan energy w/VAV
- 15-20% less refrigeration energy
- Excellent application for direct-indirect Evaporative cooling
  - Few times of the year space temperature can't be maintained.
- Maintenance Savings
  - Easy to reconfigure HVAC, Electrical, Computers wiring. Maintenance Savings
- Very low sound – library's, increased comprehension.

Distribution Systems efficiency opportunities

- Use variable air volume (VAV) systems to save energy or when room-by-room control is needed
- Constant Volume systems are easier to maintain, but use much higher energy due to fan speed and reheat.
- Consider independent mechanical rooms and systems on separate floors to reduce airflow requirements and fan energy
- Reduce duct pressure with low velocity coils and filters
- Require easy access to air handling units and filters
- Select high efficiency fans

Ductwork

- Specify duct leakage tests
- Specify duct construction details: smooth interior surfaces, smooth transitions, mastic sealant
- Locate ducts in conditioned or semi-conditioned spaces when possible

Integrated design…multidisciplinary team ….communication

What is Your Payback Requirement ?

Time Period	Annual Return on Investment

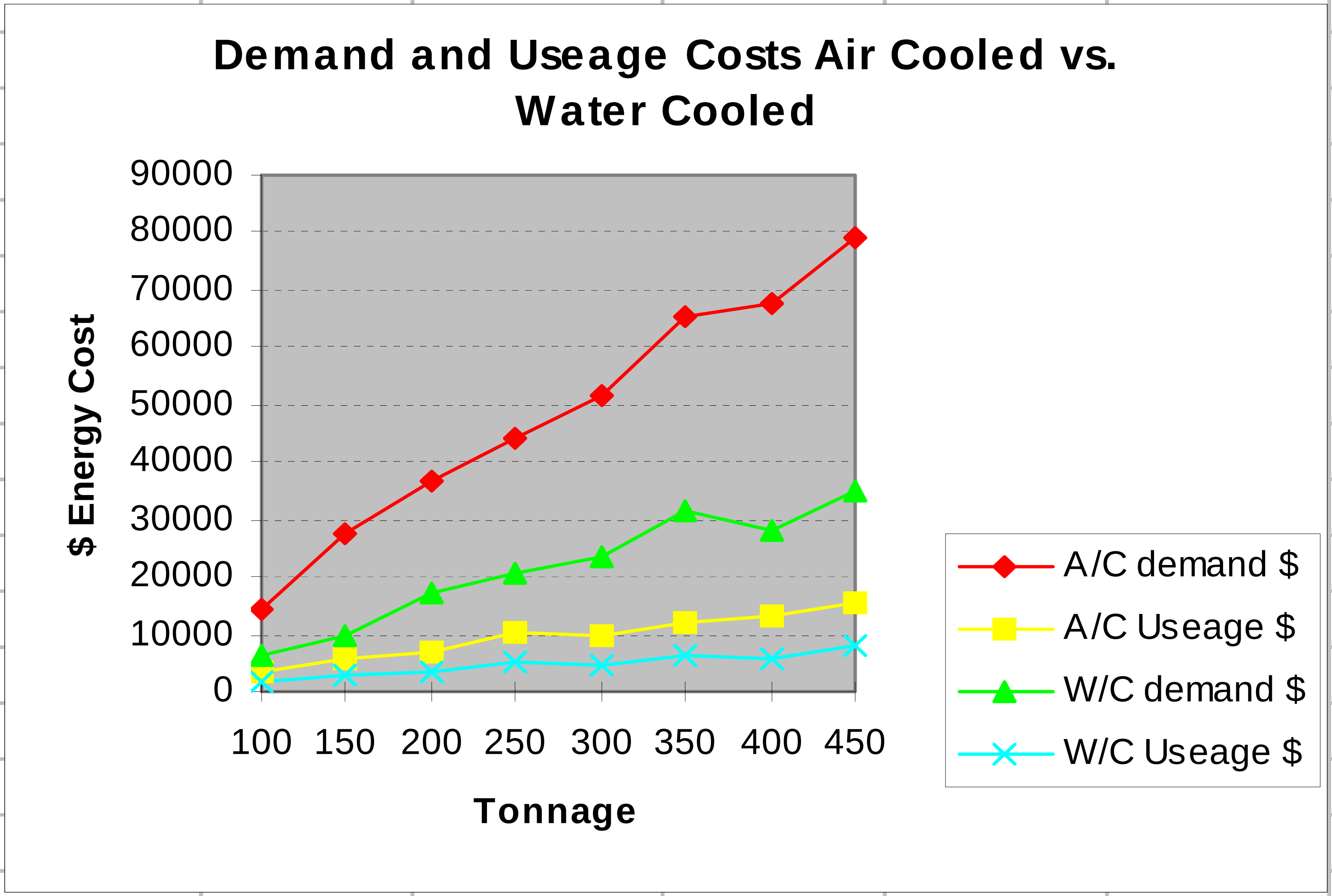
- 66 Months
- 60 months
- 54 months
- 48 months
- 42 months
- 36 months
- 30 months
- 24 months
- 18 months
- 12 months

What is Your Payback Requirement ?

Time Period	Annual Return on Investment
• 66 Months	18.18 %
• 60 months	20.00 %
• 54 months	22.22 %
• 48 months	25.00 %
• 42 months	28.57 %
• 36 months	33.33 %
• 30 months	40.00 %
• 24 months	50.00 %
• 18 months	66.67 %
• 12 months	100.0 %

Air Cooled vs. Water Cooled Chillers - First Cost and Performance Comparison in Denver

	Water Cooled	Kw/ System	Kw/ System	KW Save	Savings	
Tons	System Premium	Air Cooled	Water Cooled	@ peak	$ Per Year	
100	31,500	135	68	67		
150	18,100	204	96	108	19,350	
200	10,750	276	131	145	21,500	
250	614	334	159	175	27,176	
300	-6,225	380	179	201	32,500	
350	-3,810	478	226	252	39,400	
400	-1,730	509	214	295	46,400	
450	-11,920	594	264	330	51,600	


Demand and Useage Costs Air Cooled vs. Water Cooled
$ Energy Cost
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
100
150
200
250
300
350
400
450
Tonnage
A/C demand $
A/C Useage $
W/C demand $
W/C Useage $

Heating system efficiency options

- Consider condensing boilers
- Consider multiple, modular boilers for efficient part load
- Avoid oversizing
- Consider building as a whole: investments in shell with reduced costs of boilers & chillers

Condensing boilers

Water heating efficiency options

Consider

- Tankless water heaters or heat pump water heaters
- Localized vs centralized hot water heaters
- Solar-assisted (or design in capability to add)
- Heat recovery systems

Tankless water heaters

Commissioning

Helps ensure that the building will operate as intended…

- Schedules independent and coordinated testing to ferret out problems while crews are still on the job
- Gets past the blame game.
- Takes problem solving off the backs of the school maintenance crews
- Can include written and video training for operations staff
- Improves comfort and decreases liability from IAQ issues
- Required when going for LEED certification

The cost of commissioning

COSTS OF COMMISSIONING, NEW CONSTRUCTION

Commissioning Scope	Cost
All Mechanical and Electrical Building Systems	0.5–1.5% of total construction cost
HVAC and Automated Control Systems	1.5–2.5% of mechanical system cost
Electrical Systems Commissioning	1.0–1.5% of electrical system cost
Energy-Efficiency Measures	\$0.23–0.28/ft² (\$2.48–\$3.01/m²)

Source: Portland Energy Conservation Inc., as published in *Building Commissioning Guide* version 2.2 from the U.S. General Services Administration and the U.S. Department of Energy, July 30, 1998.

HVAC Summary

- Use whole building approach
- Energy modeling is a must
- Perform life-cycle cost analysis with several options
- Right size equipment
- Design in teaching opportunities
- Look for solutions with multiple benefits
- Commission